EXCESSIVE WATER IN GEAR OIL SHORTENS BEARING LIFE

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The additives in wind turbine gear oils can be very different for each manufacturer. Even the same manufacturer may use different additives for specific gear oils. Some of these additives absorb more water than others and may cause excessive gearbox wear[1, 2, 3]. Excess water in wind turbine gear oil is associated with many negative effects. Some of these are listed in the 2003 ANSI/AGMA/AWEA 6006-A03 wind turbine document[3] such as:

- Accelerated additive depletion
- Accelerated oxidation
- Interference with oil film formation
- Contributes to foaming
- May plug filters
- May cause corrosion etch pits and initiate fatigue cracks
- May lead to hydrogen embrittlement promoting fatigue cracks

Even as long ago as 1977, a study by R. E. Cantley at the Timken Bearing Company concluded that water in SAE 20 oil caused increased wear (See Chart 1)[2]. The Cantley formula associates 100 ppm water to 100 percent bearing fatigue life. When oil adsorbs higher amounts of water, shortened bearing life can result; whereas oil with lower amounts of water can have longer bearing life. Some gear oils like AMSOIL PTN do not adsorb excessive water and are not associated with decreased bearing life.

There have been numerous studies detailing the negative effects that water has on oil. The results seem to be similar regardless of the type of oil being tested (i.e. transmission fluid, engine oil, or gear oil). It is notable that some gear oils absorb only slight amounts of water and are not associated with increased wear, and other gear oils absorb excess water which is associated with increased wear. The U.S. Navy confirmed this with its test on automotive gear oil and concluded that when water increases from 50 to 500 ppm, there was a reduction in L_{10} bearing life by a factor of three in some oils while others were unaffected[5]. L_{10} bearing life is the life at which 10 percent of the bearings in the application can be expected to have failed due to classical fatigue failure (and not any other mode of failure like lubrication starvation, wrong mounting, etc.). This

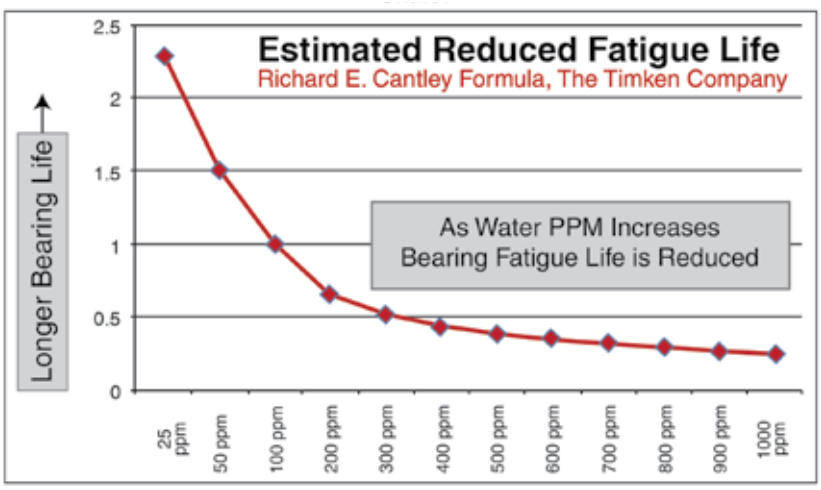

Chart 1

means that the increase to 500 ppm water caused an increase in failure rate three times that of the initial rated fatigue life.

Further documentation in 2011 of the negative effects of water on wind turbine gear oil can be found in the technical paper by M. H. Evans entitled "White Structure Flaking (WSF) in Wind Turbine Gearbox Bearings: Effects of "Butterflies" and White Etching Cracks (WEC)"[1]. Section 5.3 discusses how white structure flaking (WSF) was reproduced by adding water to a lubricant. According to Evans, the water contamination enhances hydrogen diffusion into steel which liberates on fresh surfaces in the micro-cracks, causing WSF. Evans also reports that water pulled in-between contacting surfaces results in collapsed oil film strength, causing rubbing of opposing surfaces or wear from reduced oil film thickness.

Chart 2 illustrates five different ways water can affect the operation of a wind turbine. The end result to the wind farm operator is shortened oil life, shortened gearbox life, and increased operating costs.

Choosing the right wind turbine gear oil with an enhanced lubrication additive package that resists water can improve operational costs in the following ways:

1. Longer oil life means less money spent on oil and oil changes
2. Extended gearbox life means reduced rebuild costs
3. Reduced downtime leads to increased turbine production
4. Potential for reduction in WSF related to longer gearbox run time
5. Reduced entrained air and foam relates to optimized oil film thickness and less wear

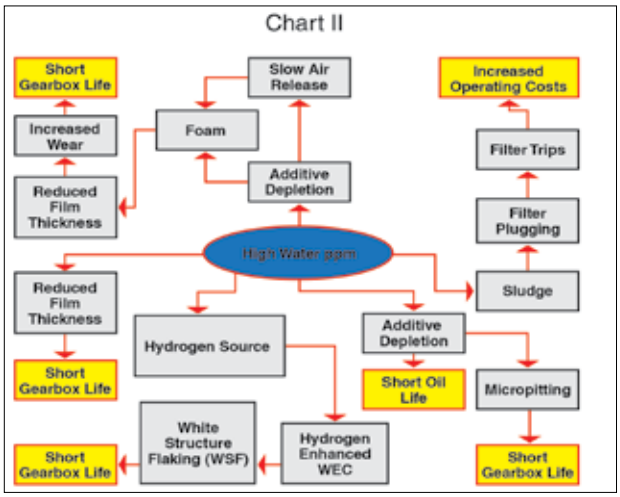

Chart 2

6. Retention of additives promote longer oil life and reduced micro-pitting wear
7. Elimination of filter plugging and low oil sensor trips and associated bonus climbs

The wind turbine industry is taking water contamination and associated wear seriously, and efforts are underway to reduce the allowable amount from 500 to 300 ppm for monitor level and from 1,000 to 600 ppm for action level[6]. Even this large reduction in allowable water ppm is not as low as European standards. The Danish Wind Standard, for example, is 200 ppm water for monitor and 400 ppm for action[4].

It is often less costly to change the gear oil to a type that does not attract water than it is to extend other efforts, including the installation of a dryer.

References:

[1] M.-H. Evans, National Centre for Advanced Tribology (nCATS), University of Southampton. White Structure Flaking (WSF) in Wind Turbine Gearbox Bearings: Effects of "Butterflies" and White Etching Cracks (WEC) Section 5.3, August 19, 2011.
[2] R.E. Cantley, "The Effect of Water in Lubricating Oil on Bearing Fatigue Life." ASLE Transactions, 20 (3), 244-248, 1977
[3] ANSI/AGMA/AWEA 6006-A03, AMERICAN NATION AL STANDARD
[4] Danish Wind Standard
[5] U.S. Navy Data – Ball Bearing (pg 36, 37, 38)
[6] ISO IEC 61400-4 Design requirements for wind turbine gearboxes, 2012